2008

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DR. MAXIMILLIAN SCHMIDT'S 1884 REVIEW OF THE GROWTH RATES OF ASIAN ELEPHANTS

[Translated from German]
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Rarely is there a scientific article of such creativity, insight and importance that it is fascinating even 125 years after it was written. The following article by Max Schmidt, translated in English for the first time, as far as we know, is one of these. As in the original article, an illustration precedes the text.

Dr. Schmidt addressed a topic of considerable interest in recent times (for example, Sukumar, 2003, Appendix 2): The growth curves of elephants. He combined data on multiple elephants from several sources to generate a table of shoulder heights from birth to the age of 34 years. For one animal at the Berlin Zoo, he provided a collection of 25 anatomical measurements repeated over a period of 20 years, perhaps the most thorough study in history of the anatomical growth of an elephant. We have modified some of the tables in the manuscript, in order to clarify them.

Among the topics Schmidt discussed are the reliability of physical measurements, growth spurts, the likely relation between diet and growth rate, sex differences in growth rate, growth rates during pregnancy, the idea that elephants continue to grow well past the age of maturity accepted at the time (20 years old) and the idea that the curvature of an Asian elephant's back changes systematically with age. Perhaps his most impressive comment is that the age at which reproductive capacity is acquired coincides with the age at which growth in the pelvic region seems complete: some time before 15 years of age.

It is no accident that Dr. Schmidt wrote such an impressive paper in 1884. He was a veterinarian who served as the director of the Frankfurt Zoo before becoming the scientific director of the Berlin Zoo in 1884, the same year this article was published (Strehlow, 1996). In 1870, Schmidt had published a veterinary manual that may be translated as "Clinical Zoology: Handbook of the Comparative Pathology and Pathological Anatomy of Mammals and Birds. Volume 1, Part 1: The Illnesses of Apes". According to Strehlow (1996), this was the first book ever published on the diseases of animals in captivity.

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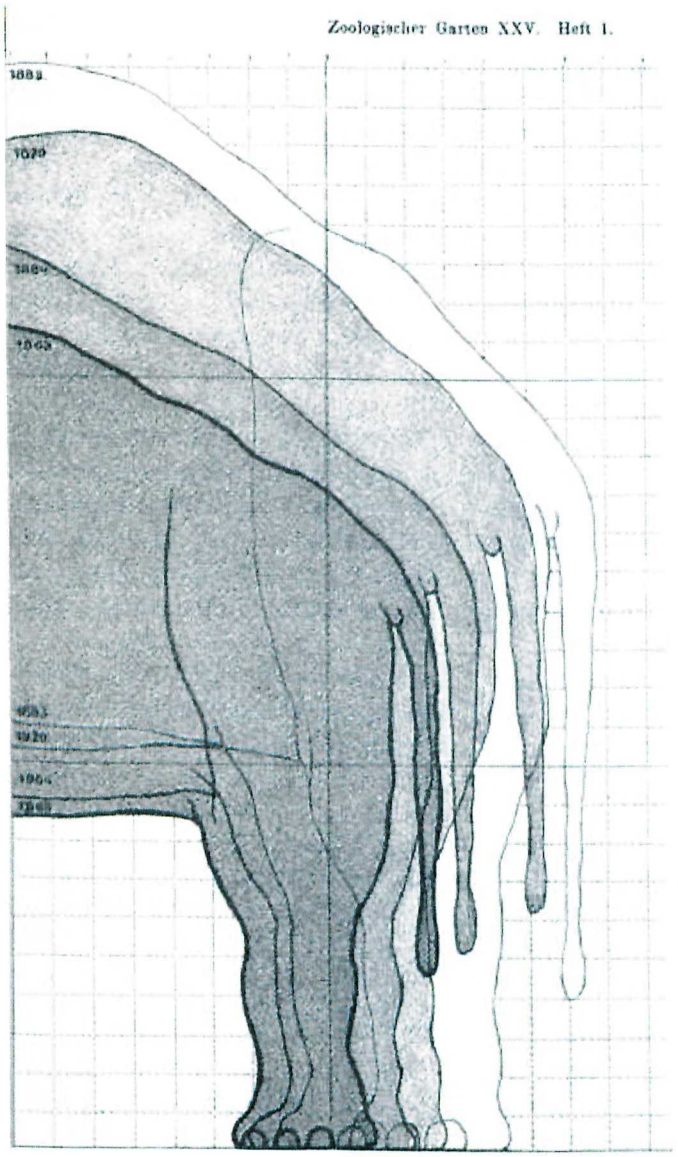

By Dr. Max Schmidt
With an Illustration
[Published in: Der Zoologische Garten, 1884, 25 (1): 4-19]

It is always highly rewarding for an animal curator when his efforts and care result in a long life for his animals. Such an undertaking has not only material benefits, although these should certainly be considered: the scientific gains that may result from it are at least as important. Like humans, animals change gradually and almost imperceptibly over the years, both in their physical appearance and in the behavior of each individual, so that we can we achieve a complete and deepening understanding of individual animals as well as, more generally, of the species only through observation and comparison.

In this respect, the Indian elephant that has lived in our zoo just over twenty years has given me the opportunity to collect some interesting observations, a few of which I will communicate.

Below I will describe the size and the growth of the animal during this period.

There is probably not another creature that grows over such a long period and is as powerful as the elephant so, occasionally, it appears worthwhile to measure the size and growth of its enormous body. While most other species would become agitated, the elephant, because of its calm and friendly nature and its willingness to be lined up and measured, allows us to measure and summarize its growth in size.

These considerations have made it possible for me to measure many physical characteristics of the elephant ever since its arrival here [Berlin Zoo] and to publish the results in this journal *(Volume 4, 1863, p. 172-173)*. In the following year I repeated the measurements and published both sets of observations for comparison *(Volume 5, 1864, p. 323)*.

I continued my observations, but it appeared appropriate to compare measurements over a longer time span, so it did not seem worthwhile to collect and publish the results every year. I measured the animal in June 1870 and again in May 1883, and present both sets of measurements here.

For the measurements themselves I worked with a straight rod marked in centimeters and a moveable T-square and, finally, with a similar apparatus with a fixed sidepiece of appropriate length that was especially well suited for measuring the width of the head, haunches, etc.

Measure (cm)	1863	1864	1870	1883
Height of highest point of the back	212	235	263	282
Height of the stomach *(in the center of the animal)*	87	92	109	109
Diameter of stomach at the highest point of the back	135	141	154	173
Shoulder height	–	220	243	260
Elbow height	–	94	100	114
Height of the croup *(inner haunch bone angle)*	–	212	235	240
Knee height	–	80	100	102
Length of the forehead from the region of the root of the trunk to the hump of the ischium	245	261	288	312
Length of the torso from the withers to the ischium (lower down back part of the pelvis)	175	187	205	216
Width of the head at the base of the ear	58	59	65	75
Width of the head at the eye socket	48	49	54	55
Height of the head from the angle of the lower jaw to the crown of the head	84	87	92	110
Width from the angle of the lower jaw to the forehead at the nostril at the root of the trunk	59	60	66	76
Width of the trunk at its root	25	25	30	34
Length of the trunk	110	110	112	131
Width of the body at the haunches *(from the outer corner/angle of the haunch-bone to the one on the other side)*	96	98	100	125
From the outer corner/angle of the haunch-bone to the stifle joint *(knee-cap)*	90	100	139	149
From the outer corner/angle of the haunch-bone to the root of the tail	60	70	78	78
Width of the hind-foot at the knee-joint *(viewed from the side)*	50	50	52	57
Breadth of the sole of the rear foot	23	24	36	37
Length of the sole of the rear foot	36	37	40	41
Breadth of the sole of the front foot	30	30	30	36
Length of the sole of the front foot	31	31	35	41
Length of the tail	100	100	100	133
Height of the root of the tail	144	155	155	173

Even a preliminary look at the table indicates that the animal developed at a uniform rate according to all measures. Not surprisingly, the elephant exhibited a symmetrical physique during the different stages of growth. The animal's contours were designed in a pattern, presented in centimeters. Observation of the elephant itself offers complete confirmation, and we must accept, therefore, that it had a completely normal pattern of growth. With some certainty we can say that we obtained our elephant at an age of about 14 years old. When it arrived in Europe it was about 7 years old according to estimates made in India and the opinion of its caretaker at that time. We can document easily that the animal remained in captivity at other facilities for seven years before coming into our possession. Therefore, the data above represent an overview of the growth of an elephant from 14-34 years of age.

We are at present attempting to deliver hard evidence, based on what is already known about the rate of growth of these animals, concerning the circumstances under which growth occurs during the different stages of life.

Unfortunately, there are very few data in the literature, with precise measurements, especially when it comes to measurements taken over a long period of time. In recent times, there are only two sets of measurements collected from four elephants at the London Zoo, so we have had to rely mainly on the older data.

It would be advisable at the start to determine the size of the newborn elephant, which leads us to a study worthy to be mentioned first and foremost. This work is the *"Observations on the Manners, Habits and Natural History of the Elephant"*, by John Corse *(Philosophical Transactions of the Royal Society of London, 1799, P. 31-55)*.

Corse, as stated at the beginning of his article, lived for more than 10 years in Tiperah, a province of Bengal at the boundary of the eastern possessions of the English in India. Annually, between 1792 and 1797, he captured groups of elephants, and their management was completely under his control. He had several opportunities to observe parturition: one elephant calf was born with a height of 35.5 inches = 90 cm, and another was born in captivity in India with a height of 35" = 82 cm [sic, actually 89 cm]. Corse positively observed that the calves of wild females captured while pregnant had rarely exceeded the height of 34" = 86 cm.

I found only one other recent observation, presented by George Arstingstall, the elephant trainer for Barnum, Bailey and Hutchinson *(the largest circus in America; Journal of Comparative Medicine and Surgery, 3 (2), New York, April, 1882, pp. 146-153)*. According to this account, an elephant born on 2 February 1882, and measured 2 hours after birth had a height of 76 cm and a weight of 145 lb.

Furthermore, Corse reported the observations made, over a period of several years, on a calf owned by a Mr. Stephen Harris, born on 16 October 1789 {corrected from the original data given}. This amounted to:

Age	Annual Growth *(cm)*	Height *(cm)*
Birth	–	89[a]
1	28	117
2	21	138
3	15	153
4	12.5	165.5
5	12.5	178
6	9	187
7	5	192

[a] *Birth height = 89 cm, subtracting the animal's first-year growth from its height at one year*

In November 1796, at 20 months of age, this calf (referred to here as Corse #1) was 136 cm tall.

A female elephant, which was 206 cm tall when received by Corse, and whose estimated age was approximately 11 years, grew 15 cm during the next five years. The animal, which we will refer to as Corse #4, was bred and grew 13 cm during a 22-month pregnancy. During the following 17 months its height increased by only 1.5 cm. It was then 19 years old and, by Corse's estimate, full-grown. Its height was then 235.5 cm.

An additional study, which contains useful information for our purposes, is Houel's, "Histoire naturelle des deux Elefants, male et femelle du Museum de Paris, venus de Hollande en France en l'an VI. Paris. An XII. (1803) Fol." [Natural history of two elephants, a male and a female, at the Museum of Paris, having come from Holland to France in Year 6 [in the Post-Revolutionary Calendar]." (Year 12 (1803) Fol.)]

The author observed the animals over a longer time period and published precise observations, along with a series of etchings. We obtained the following observations from his work concerning the age and the size of the two elephants:

They were seven years old in 1788, and thus 15 years old when they came to Paris in 1796. At that time, the male was 237 cm and the female was 227 cm at the withers. The male (Houel #5) died at the age of 20 years in 1801, when its height at the withers was 248 cm. Two years later, in the year 1803, the female (Houel #6) who was now 22 years old, was 246 cm tall.

The most recent set of observations came from four individuals at the Zoological Garden of London (Proceedings of the Zool. Soc. of London, 1879, P. 385 and 1881, P. 450). Only the shoulder height and the front-foot circumference of each elephant were measured in feet and inches, which we will convert to cm after this point.

	Date			
	May, 1879		April, 1881	
Animal (Sex)	Shoulder Ht.	Fr Foot Circumf.	Shoulder Ht.	Fr Foot Circumf.
Jung Pershad (M)	7'0"	23'8"	8'0"	4'0"
Suffa Culli (F)	6'10"	3'8"	7'6"	3'9"
Rustum (M)	6'0"	2'11"	6'4"	3'2"
Omar (M)	6'2"	3'2"	7'0"	3'6"

The increase over two years amounted therefore to:

Elephant	Shoulder Height	Front Foot Circumference
Jung Pershad (M)	1'0"	8'0"
Suffa Culli (F)	0'8"	0'1"
Rustum (M)	0'4"	0'3"
Omar (M)	0'10"	0'4"

Suffa Culli was born on April 23, 1871 of a wild-caught mother and Jung Pershad was estimated to be 6 years old in 1876. We do not have even approximate information on the other two animals, so we will not consider them any further. I will refer to the male Jung Pershad as London #2 and to Suffa Culli as London #3.

To appreciate the data from these animals, we try not to err, but to correct an erroneous view. From dealers and animal-show owners we often hear that the height of an elephant is double the circumference of the front foot. This is likely to be correct for elephants of a certain age, but we can show that this estimate is not generally correct, because later growth variations may be considerable. The circumference of the front foot of the elephant in our zoo was 1.17 m, which [according to the rule] would correspond to a shoulder height of 2.34 m. The shoulder height of the animal was actually 2.60 m.

This might be the point at which to consider the most suitable site for measuring the height of an elephant, because there is sometimes doubt about whether to measure the elephant at the highest point on its back or at the withers/shoulder.

Obviously, the shoulder is the correct point for determining the height of an elephant because the skeleton is firmly joined at that spot, allowing for no significant fluctuations at this point. The more the elephant moves, the more the back arches, because this height depends on a very flexible spinal column which changes position based on the animal's age, its position and on a variety of other factors. Corse reported on this case, that the elephants, which he had purchased as workhorses for the East Indian Company, were measured at the shoulder, and for that reason we have also passed on his assertion concerning his height measurements without requiring the details of the position. Furthermore, he noticed, that the upward bend of the back gradually decreases for the full-grown elephants. According to his observations, a small decrease in the curvature of the spine that occurred among young elephants, he was confident, was due to external causes. He had seen that in newly captured elephant herds, the older animals, whether male or female, with the base of their tusks, forcibly pressed down on the backs the young individuals, in such a way that they vigorously arched themselves and bellowed because of the pain.

I follow now with a clear summary of the previously published measurements of elephants' heights to the following well-ordered sequence of the ages of the animals. Values derived through calculation rather than through actual measurement are indicated with *.

Age (years)	Description of specimen	Shoulder height (cm)	Growth (%)
Newborn	According to Arstingstall 2 February 1882, born in America	76	–
Newborn	According to Corse (Male) 16 March 1795, born in India	90	–
Newborn	According to Corse (Mr. Harris's elephant: Corse #1) 16 October 1789, born in India	89	–
1	Corse # 1	117	31.5
20 months	Male born on16 March 1795	136	–
2	Corse # 1 (November 1796)	137	17.1
3	Corse # 1	152	11.0
3	Houel, an elephant shown by a traveling entertainer in Paris	153	–
4	Corse # 1	164.5	8.2
5	Corse # 1	177	7.6
6	Corse # 1	186	5.1
7	Corse # 1	191	2.7
8	Suffa Culli (female)	209	–
9	Jung Pershad (male)	214	–
9	Suffa Culli	*219	4.8
10	Suffa Culli	229	4.6
10	Jung Pershad	*229	7.0
11	Jung Pershad	244	6.6
11	Corse # 4 (female)	206	–
12	Corse # 4	*209	1.5
13	Corse # 4	*212	1.4
14	Corse # 4	*215	1.4
14	Frankfurt Zoo (female)	–	[back height 212 cm]
15	Frankfurt Zoo (female)	220	[back height 235 cm]
15	Houel # 5 (male)	237	–
15	Houel # 5 (female)	227	–
15	Corse # 4	*218	1.4
16	Corse # 4	221	1.4
16	Houel # 5	*238	2.5
16	Houel # 6	*230	1.2
16	Frankfurt	*224	1.7
17	Houel # 5	*238	2.5
17	Houel # 6	*232	1.2
17	Corse # 4	*228	2.9
17	Frankfurt	*228	1.7
18	Houel # 5	*239	2.5
18	Houel # 6	*235	1.2
18	Corse # 4	234	2.9
18	Frankfurt	231	1.7
19	Houel # 5	*239	2.5
20	Houel # 6	*241	1.1
20	Frankfurt	*239	1.6
21	Houel # 6	*243	1.1
21	Frankfurt	243	1.7
22	Houel # 6	246	1.1
22	Frankfurt	*244	0.5
23	Frankfurt	*246	0.5
24	Frankfurt	*247	0.5
25	Frankfurt	*248	0.5
26	Frankfurt	*250	0.5
27	Frankfurt	*251	0.5
28	Frankfurt	*252	0.5
29	Frankfurt	*253	0.5
30	Frankfurt	*255	0.5
31	Frankfurt	*256	0.5
32	Frankfurt	*257	0.5
33	Frankfurt	*259	0.5
34	Frankfurt	260	0.5

Fortunately, the data sets listed complement one another, so that the result is a sequence that shows the annual increase in height for elephants from birth to 34 years of age. Although not all of the measurements are of living animals, they are similar enough that the resulting curve is probably reasonably accurate.

First of all, the table shows a decrease in growth rate as the elephants become older. The growth rate in the first year of life is the most significant and measured about 31.5%. This fell to a growth rate of only 2.7% by the seventh year. The elephants from London, which provided our data for elephants between 8-11 years old, grew more quickly, so that the growth rates do not fit in smoothly with the rates for the previous elephants. This higher growth rate also occurred for the 17-to-18-year-old elephant (Corse #4), which grew faster than the elephants in the chart that were younger than 17 or older than 18 years of age. It may be that these elephants in London were especially well-nourished and received good care. The Prince of Wales brought these elephants to England from India and they were undoubtedly selected because they were particularly attractive and fit animals, which had probably already received unusually good care in their homeland. Comparing the height of the eight-year old female from London (Corse #2) with that aforementioned seven-year old individual (Corse #1) produced a difference of 18 cm. This would correspond a growth of 9.4% during the eighth year of life, which appears much too high compared to the previously mentioned examples. We are probably correct to expect that growth progressed unusually and we will have to wait to find out whether the animals at the London Zoo continue to grow as they have until now, or whether annual height increase

will decrease remarkably for a few years, after which time these animals will not substantially exceed the average elephant size.

Corse's Elephant # 4 provides an example of a growth spurt. Between 11-16 years it only grew 5 cm in height, then suddenly grew 13 cm in the next 22 months, followed by growth of only 1.5 cm in the ensuing 17 months. This growth spurt is surprising given that the elephant was pregnant and one should expect that the rate of growth would decrease rather than increase during this period. Corse states specifically that the faster growth was probably due to enhanced care and ample nourishment given during the pregnancy. Between 7-11 years of age this animal grew at a more normal rate. If we assume that it was 191 cm high at seven years of age, like Corse # 1, then that yields an annual growth of approximately 3.7 cm, which corresponds to a change of between 1.8-2.0%. These numbers are very similar to those obtained for younger and older age groups.

Between 16-22 years of age we have a particularly rich sample of data, including the similar growth rates of the local [that is, in Berlin] female and the female elephant living in Paris (Houel # 6). The average growth rate for both animals over the years 16-21 is 3.2 cm/year, equivalent to a growth rate of 1.39-1.45 %/year, and for the 22nd year of life the growth rate was 2cm = 0.82% annually. Between 22-34 years the annual growth rate of the local [Berlin] elephant was only 1.3cm/ year (about 0.5%). While the data in our table exhibit a continuous rate of growth for the female elephants, which we have every reason to assume to be accurate, the incomplete reports for the male elephants still provide no clear picture of their rate of growth. It might reasonably be expected that the males would have a considerably greater rate of annual growth than the females. This growth rate of the female elephants in London was 4.78% and 4.57% respectively, during the 9th and 10th years, while in comparison the males gained 7.01% during the 10th year and 6.55% during the 11th year. The relationship was similar for the Parisian elephants: the male (Houel #5) grew at an annual rate of 2.51-2.53% during its 16th-20th years, while the female of the same age (Houel #6) grew at a rate of only 1.14-1.19 %.

A male elephant in the Amsterdam Zoo, about which we will write below, was 2.77 m tall at the age of 23 years, while our [Berlin Zoo] female elephant of the same age was only 2.46 m tall and a 22-year-old female in the Paris zoo (Houel #6) was 2.46 m tall.

We should not be surprised by the fact that male elephants grow faster than females because in all other species, as with the elephant, the male animals grow larger.

We must now ask ourselves how long elephants continue to grow. The usual account is that elephants are full-grown by 20 years of age. Corse concluded similarly on the basis of his observations, but makes note of an elephant that was still growing at 22 years old.

As far as I can recall, the long bones and their epiphyses had not fused in the skeleton of the male elephant that arrived at the Amsterdam Zoo on 7 August 1849 and lived there for 23 years before it died, from which we are justified to conclude that it was not yet full-grown. Finally, we have more evidence for continuous growth from an animal that has lived in our zoo for 34 years and is not yet fully-grown, or has only recently reached full maturity. During the years 1864-1870, during which the animal was 15-20 years old, the elephant grew around 23 cm at the shoulder; during the years 1871-1883, at the ages of 21-34 years, its shoulder height increased by about 17 cm. Over this period the growth rate of 1.3 cm/year still seems too high to me, if growth indeed had ended, but we will probably have to wait until our animal's 25th anniversary in our garden before we can make a final decision in this matter.

Meanwhile we have every reason to accept that the elephant is not full-grown at twenty years, and perhaps not even until at least the thirtieth year. I want to emphasize here that our animal still has an arched back, which one gets used to regarding as the adolescent form, while as a rule other equally old elephants are highest at the shoulder, while their backs take a straighter line and some fall away towards the hindquarters. Does this configuration perhaps suggest a continuation of growth?

It is beyond all doubt that elephants are capable of reproduction before they are full-grown. This is proven by the female elephant mentioned above (Corse # 4) and in addition by the deceased male specimens, which had to be killed because of musth (rut-madness) long before they completed growth.

One may ask how tall an elephant can become, and the answer would have to be considered through discussing the growth conditions of this genus of animal. Unfortunately, this seems to be farther off than it did at the end of the previous century, at least it seems to me that new evidence has not come forward. Concerning these topics, Corse shared the following with us.

The size of elephants at the shoulder is often overestimated and, in India, generally does not exceed 7-8 feet (223-244 cm) for the female, and 8-10 feet (244-305 cm) for the male. Our informant found only one elephant, which exceeded the latter [height]. This was a male, which was measured on 18 June 1796, resulting in the following dimensions *[Note: While it is of minor importance, the metric conversions are inexact]*:

From one front foot to the other, measured over the shoulder	22'10.5"	= 698 cm
Shoulder height	16'6" [sic]	= 320 cm
The top of the head at the usual position	12'2"	= 369 cm
From the forehead to the root of the tail	15'11"	= 438 cm

There was another case of an elephant that was supposed to be 14' high and that Corse, when he saw it, estimated to be 12', but its measured height was only 10' = 305 cm. Of about 150 elephants used in Bengal, not one of them was 10' high, and only a few males were 9.5' = 2.88 cm tall. [9.5' = 290 cm].

The standard shoulder height for the elephants owned by the East India Company was determined to be 7' = 214 cm.

Corse indicated, after comparing Indian elephants and [Sri Lankan] elephants from Ceylon, that it was also the case that neither of the sub-species of Indian elephant exceeded the suggested limit in body stature. Here it resulted that the latter was, contrary to common opinion, neither larger nor more useful than the former.

We have managed a detailed consideration of the course of growth of the Indian elephant with an investigation of the observations, permitting us to pay thoughtful attention to the growth rates of specific parts of the body. If we compare the increase in shoulder height of the local animal [Berlin] with that of the highest point on the back as well as with that at the croup, then we notice that the growth of the first two items mentioned is far more active than the last one mentioned. The growth during the 19 years between 1864 and 1883 is shown below (The heights of the shoulder and the croup were not measured in 1863):

The height of the animal amounted to:

	Shoulder height	Back: highest point	Croup
1864	220 cm	235 cm	212 cm
1870	243 cm	263 cm	235 cm
1883	260 cm	282 cm	240 cm

This resulted in an increase over the years:

	Shoulder height	Back: highest point	Croup
1864-1870	23 cm	28 cm	23 cm
1871-1883	17 cm	19 cm	5 cm
	40 cm	47 cm	28 cm

Consequently, the average annual growth for the period amounted to:

	Shoulder height	Back: highest point	Croup
1864-1870	3.8 cm	4.6 cm	3.8 cm
1871-1883	1.3 cm	1.6 cm	0.4 cm

We see from this that in the years 1864-1870 the height increases were similar at the shoulder, the back and the croup, but during 1871-1883 the shoulder height and back height exhibit relatively similar increases, compared to which the lumbar region (rump) grew only slightly.

The heights of the knees relative to the heights of the elbows at different times were:

	1864	1870	1883
Elbow	94 cm	100 cm	114 cm
Knee	80 cm	100 cm	102 cm

This yields the growth of the elbow and the knee during the periods:

1864-1870	Elbow = 6 cm	Knee = 20 cm
1871-1883	Elbow = 14 cm	Knee = 2 cm

Consequently, the breakdown of the animal's overall [shoulder] growth into the growth of its torso and its limbs is as follows:

	Shoulder height	Torso	Limbs
1864-1870	23 cm	17 cm	6 cm
1871-1883	17 cm	3 cm	1 cm *[should be 14 cm: see next paragraph]*

	Growth at the croup	Torso	Limbs
1864-1870	23 cm	3 cm	20 cm
1871-1883	5 cm	3 cm	2 cm

From these data, it appears that the hind-parts completed their growth before the foreparts. The latter grew by 40 cm, whereas the hind-parts grew only 28 cm, during the same 19-year period. From 1864-1870, corresponding to the 15th-21st years of the animal's life, the torso grew by 17 cm, while the legs grew only 6 cm. It is obvious that, essentially, the torso had completed its development, since in the following 13 years of life, from 1871-1883 (Ages 22-34 of the animal) it only grew by 3 cm, during which time the leg up to the elbow grew 14 cm.

The hind-parts were full-grown and, overall, the pelvic area was completed in 15 years, then from that time until 21 years of age the torso grew only 3 cm higher, whereas the legs grew by 20 cm. Thus we have here a relationship opposite to that for the front part during the same time period. The growth of the hindquarters can also be, essentially, regarded as completed, because the increase of around 5 cm demonstrated during the following 13 years, and that was rather equally distributed between the torso and the limbs, can hardly be considered significant. According to the assembled data, the age at which the pelvis and lower bowels have reached maturity coincides fairly precisely with the age at which the reproductive capacity tends to emerge.

This reference may be sufficient to suggest which information about the growth of elephants can be gained through measurement. With the limited amount of material available up until now, it would be premature to draw general conclusions. This article will have achieved its purpose if it provokes other zoological gardens into collecting similar data. ❖